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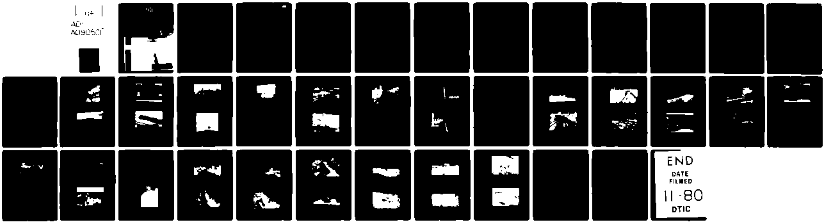

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REPORT 80-17

Snow pads used for pipeline construction in Alaska, 1976

Construction, use and breakup

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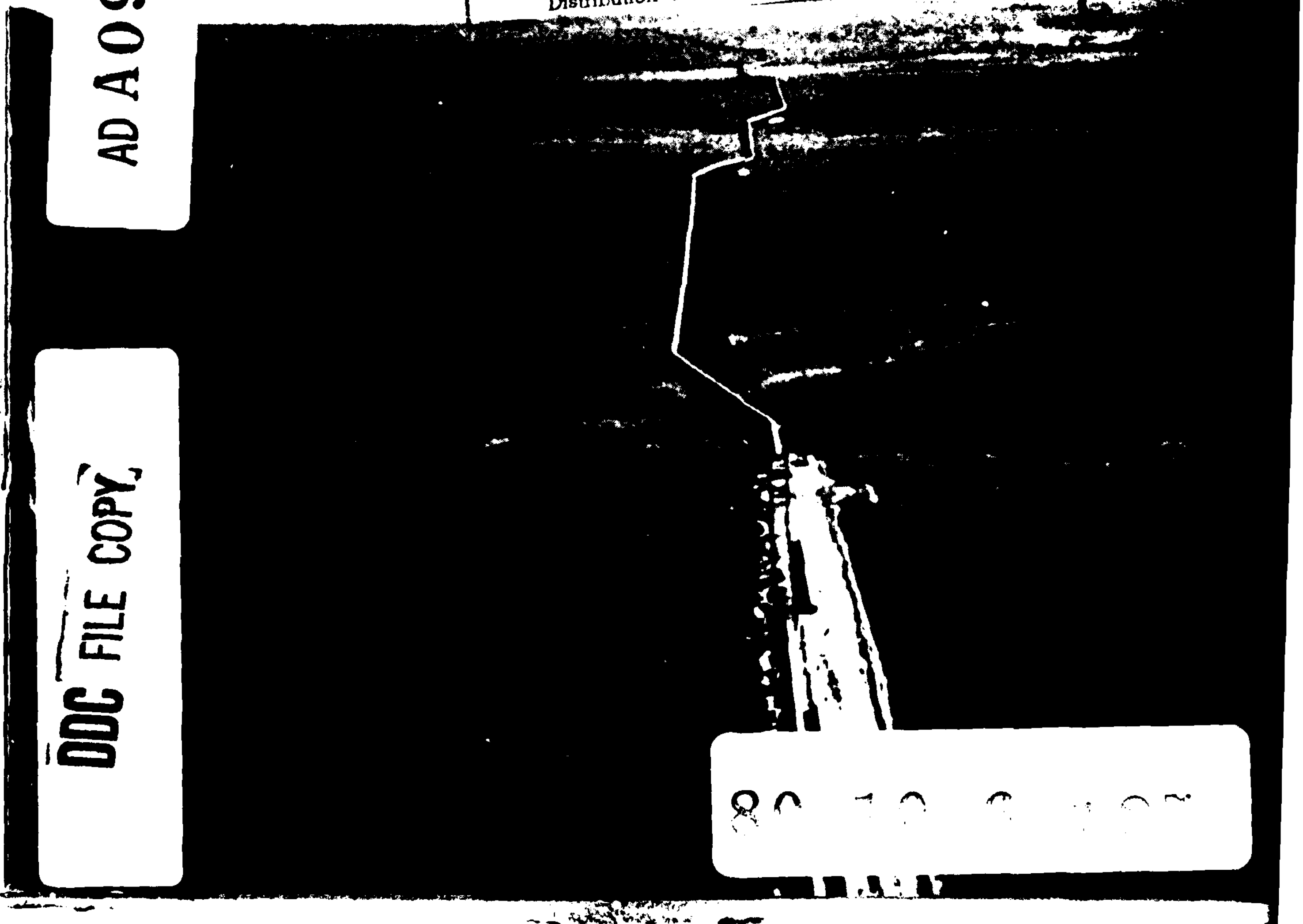

For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380, Metric Practice Guide, *published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.*

Cover: *Aerial view of the Alyeska Pipeline constructed from a gravel pad (foreground) and from a snow pad. (Photograph by John Zarling.)*

CRREL Report 80-17

Snow pads used for pipeline construction in Alaska, 1976

Construction, use and breakup

Philip R. Johnson and Charles M. Collins

July 1980

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Construction pads made of snow were used to build two sections of the Trans Alaska Pipeline and a small gas pipeline during the winter of 1975-76. Construction during the winter has become increasingly common in the Arctic. Surface travel and the use of heavy construction equipment on the unprotected tundra have been severely restricted, even during the winter, so the use of temporary winter roads and construction pads built of snow and ice has been advocated and is being adopted. The three snow construction pads mentioned above were the first snow roads and construction pads used on a large scale in Alaska. Snow roads and construction pads have two objectives: to protect the underlying vegetation and upper layers of the ground, and to provide a hard, smooth surface for

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travel and the operation of equipment. Several types have been built, and a brief discussion is given of their history and classification systems. The three snow construction pads used in construction of the Trans-Alaska Pipeline and the small gas pipeline in 1975-76 were visited and observed while in use.

The Globe Creek snow pad, about 50 miles north of Fairbanks, was built primarily of manufactured snow hauled to the site and watered. With very high densities this pad withstood heavy traffic and use by heavy construction equipment except on one steep slope. There, the use of tracked vehicles and vehicles without front wheel drive disaggregated the snow on and near the surface so that vehicles without front wheel drive were unable to climb the hill. The Toolik snow pad, just north of the Brooks Range, was built of compacted snow and proved capable of supporting the heaviest traffic and construction equipment. The fuel gasline snow pad ran from the northern Brooks Range to the Arctic Coast and also proved capable of supporting the necessary traffic. Both the Toolik snow pad and the fuel gasline snow pad failed in very early May because of unseasonably warm and clear weather before the associated construction projects were completed. However, the three snow pads must be considered successful. Common problems were the lack of snow, slopes, unseasonably warm spring weather, and inexperience on the part of contractors and construction personnel.

PREFACE

This report was prepared by Philip R. Johnson, Research Civil Engineer, and Charles M. Collins, Physical Scientist, of the Alaskan Projects Office, U.S. Army Cold Regions Research and Engineering Laboratory.

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The authors express their appreciation to the staff of Alyeska Pipeline Service Company, who allowed them to observe the snow construction pads during their construction, use and decay. They also acknowledge the assistance of the staff of the Alaska Pipeline Office, U.S. Department of Interior, for their support and assistance during these studies: they are particularly indebted to Rudy Berus and Arthur Olien, who served jointly as Alaska Pipeline Office representatives on the North Slope.

E.S. Clarke of Clarke Engineering Co., Fairbanks, Alaska, and G. Abele and F.E. Crory of CRREL reviewed the technical content of this report.

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Construction, Use and Breakup

Philip R. Johnson and Charles M. Collins

INTRODUCTION

It is well known that standard wheeled or tracked heavy equipment operating on the arctic tundra damages the vegetative layer in many cases. This damage increases the depth of summer thaw and may lead to melting of interstitial ice and segregated ice such as ice lenses and wedges. This, in turn, leads to subsidence of the surface and may lead to water erosion. Currently cross-tundra travel is severely restricted during the summer on the Alaska arctic tundra.

In the winter, special types of equipment such as the Rolligon are allowed to travel across the snow-covered tundra after the active layer is partly or entirely frozen, but most other wheeled and tracked equipment can operate only if the tundra vegetation is protected. Snow and ice roads and pads are becoming fairly common types of protective systems. Alyeska Pipeline Service Company first used three separate snow pads for construction during the winter of 1975-76, and the authors were allowed to examine these pads and observe their behavior.

This report is primarily confined to the engineering aspects of the snow pads: their construction, their ability to support traffic and equipment, and their breakup in the spring. Studies of the impact or lack of impact of the North Slope snow pads on the underlying vegetation and permafrost are reported in Brown and Berg (1980).

HISTORY OF SNOW AND ICE ROADS

Man has recognized the advantage of a packed trail since he first began to walk in and on the snow. Packed trails are still used today by cross-country skiers and snow machine drivers. Deliberate packing on a larger scale was a feature of colonial days when horse-drawn rollers and drags were used to pack roads and trails. Packing also became a standard practice in coping with snow on northern airfields in the early days of aviation and continues in use today.

A new type of snow travel, requiring more intensive road and airfield preparation, was a feature of the installation of large radar units on the Greenland Ice Cap in the early 1950's. Engineering and scientific studies were carried out and special equipment and techniques were developed to obtain the relatively deep packing and strong surfaces required for heavier equipment and aircraft. This work was continued and expanded with the development of research programs in the Antarctic in the 1960's. The principal research organizations concerned were the

U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and the U.S. Naval Civil Engineering Laboratory (NCEL). The literature based on this work is too extensive to review here but Abele et al. (1968) provide an excellent summary.

The concept of using snow and ice roads for temporary travelling surfaces which protect the underlying vegetation and permafrost developed in the late 1960's and early 1970's. Scars resulting from earlier activity in Naval Petroleum Reserve No. 4 (NPR4) in northwestern Alaska (Hok 1969) and the development of heat transfer studies (Lachenbruch 1959) indicated the need to maintain the insulation value of the tundra. A study by Knight (1969) demonstrated that heavy tracked and rubber-tired construction equipment could be successfully operated on a pad of compacted snow.

During mobilization for construction of the Trans-Alaska Pipeline, the "Hickel Highway," a winter trail from Livengood to the North Slope, was built in the winters of 1968-69 and 1969-70. Crossing the Yukon River on an ice bridge at Stevens Village, this winter road proceeded northward through Bettles and Anaktuvuk Pass to Toolik Junction. From this point north of the Brooks Range, two winter trails proceeded, one eastward to Toolik and one north and then east to Sagwon in the Sagavanirktok River Valley. In addition, Alyeska built 90 km (56 miles) of the Haul Road from a point on the existing Alaska road system near Livengood to the Yukon River.

When Congressional approval of pipeline construction was given, Alyeska again used much of this road system for mobilization of equipment and construction crews during 1974-1975. The Haul Road segment to the Yukon River was used, together with ice crossings on the river during the winter, and a ferry system during the summer at the bridge site. A winter trail north to Old Man connected with the "Hickel Highway" and the northern portions of this trail were again used. This trail system was invaluable for mobilizing to build camps and for bringing in equipment and supplies to build the Haul Road. Once the Haul Road was built, construction began on the pipeline, pump stations and other permanent facilities.

In addition to the winter trails, Alyeska built a snow runway during the winter of 1974-75 at Coldfoot Camp that was used successfully by Hercules C-130 and executive jet-type aircraft.

During the winter of 1975-76, Alyeska used snow pads to construct two sections of the large, 48-in.-diameter pipeline at Globe Creek and Toolik, and another snow pad to construct a small natural gas pipeline from Prudhoe south to Pump Station 4 (Keyes 1977).

CLASSIFICATION OF SNOW AND ICE ROADS

A great deal of confusion exists in the terminology used in describing winter roads, trails and pads in the north. In part, this is because many of the methods and materials used are new, the work is widely scattered, and standard techniques have not yet been developed.

Adam (1978) defined winter roads and trails on the basis of the type of material and construction used.

A *winter road* is any type of road built of snow, ice, or a mixture that remains functional during the winter season.

1. The *winter trail* is established by a single pass of a wheeled or tracked vehicle using a blade if necessary to gain access and can be seasonal or perennial.

2. The *snow road* can be built of compacted snow or processed snow, or ice-capped.

3. *Ice roads* consist of solid ice, aggregate ice, winter roads on frozen lakes or rivers, and ice bridges.

The Alyeska Pipeline Service Company developed a performance classification defining five types of snow pads for pipeline construction. Types I-IV are for handling traffic of increasing weight and impact on the pad. Type I would carry low-ground-pressure equipment while Type IV would carry concentrated construction equipment. Type V is a steep slope snow pad that requires special design. The minimum snow thicknesses, densities and ram hardnesses for Types I-IV are specified and construction procedures have been developed. The Alyeska Snow Work Pad Design Criteria chart, in part, is given in Table 1.

The Adam and Alyeska snow road and pad classification systems are complementary. Adam provides a descriptive classification based on the type of material and construction used. Alyeska provides a set of engineering requirements and then describes how these can be met using specified quantities of materials and

Table 1. Alyeska snow work pad design criteria.

Type	For equipment	Minimum snow thickness at density	Construction procedure
I	Low ground pressure Rolligons Nodwells Crawler tractors Sleds 4WD trucks with wide tires	3 in. at 32 lb/ft³ (0.51 g/cm³)	Following refreeze of the active layer to 1 ft and accumulation of 6 in. of 18 lb/ft³ snow, construction can begin. Rolligons and Nodwells will not require any trail preparation except clearing. Periodic use of a drag or roller will increase travel speed of Nodwells and Rolligons, remove ruts and create a surface suitable for occasional traffic with four-wheel drive trucks with wide tires.
II	Light equipment Pickups Light trucks with axle loadings less than 8,000 lb	3 in. at 38 lb/ft³ (0.61 g/cm³)	Treatment as above plus 8 passes with crawler-type tractors and drags or vibrating rollers with 1 week of sintering at 15°F, or 2 passes with drags or vibrating rollers with 2 weeks of age hardening at 15°F, or 2 passes with crawler-type tractors and drags or vibrating rollers with addition of water and refreezing for immediate use.
III	Heavy trucks to axle loadings of 20,000 lb	6 in. at 44 lb/ft³ (0.70 g/cm³)	Treatments as above plus an additional snow accumulation of 6 in. Additional compaction until the upper range of density is achieved, or addition of water until a ram hardness of 600-1,000 is reached.
IV	Concentrated construction Trucks with axle loadings above 20,000 lb Locked-track turning of tracked vehicles	12 in. at 50 lb/ft³ (0.80 g/cm³)	Treatment as above plus an additional snow accumulation of 1 ft, and addition of water to saturate the upper 1 ft of snow.
V	Steep slope construction Longitudinal slopes exceeding 15% for distances greater than 200 ft. Transverse slopes exceeding 5%.		Special design required.

procedures for processing them. An urgent need exists for development of a comprehensive nomenclature for winter roads, trails and construction pads built of ice and snow perhaps based on Adam's system but expanded. The Alyeska engineering specifications need to be evaluated in terms of performance.

Water applied to a snow pad or road during freezing conditions serves several functions. If not applied in excessive quantities, it is generally retained in the upper part of the snow pad in the areas of inter-grain contact. Upon freezing, it greatly increases the strength of the inter-grain bonds and thus the strength and hardness of the snow. Such bonds form very rapidly compared with the rather slow hardening of unwetted packed snow. Further, the water increases the density and reduces the porosity of the snow. If repeated light applications of water are made, an ice cap that makes a strong wear-resistant surface can be formed.

Methods of testing snow pads generally consist of ram hardnesses and density measurements. Ram hardnesses of snow are obtained with a Rammsonde Cone Penetrometer (Ueda et al. 1975). Ram hardness values can be correlated, to some extent, with compressive strength (Abele 1963) and can be used to determine the load supporting capability of the snow (Abele et al. 1968). The Rammsonde Penetrometer, using a 60° cone, was originally designed for natural snow with ram hardnesses up to 200. A 30° cone

for use in processed, age-hardened snow was developed and evaluated (Niedringhaus 1965), and has proved to be useful in measuring snow with ram hardnesses up to 1000.

Density samples for this study were obtained with a CRREL 3-in. ice coring auger. Samples were divided into sections; they were then measured and weighed, and their densities calculated.

SNOW PADS USED BY ALYESKA DURING THE WINTER OF 1975-1976

The Globe Creek snow pad

About 50 miles north of Fairbanks the Trans-Alaska Pipeline crosses Globe Creek and, proceeding south, climbs a moderately steep slope to reach the top of a ridge. Exploratory drilling showed that the lower part of this north-facing slope consisted of ice-rich permafrost. An analysis indicated that building a gravel pad for construction of the pipeline would alter the thermal balance at the site and initiate thawing of the permafrost, thus threatening the integrity of the vertical support members carrying the pipeline. It was determined that a snow pad could be used for construction with less effect on the thermal regime and the permafrost. The snow pad was 760 m (2500 ft) long, and 20 m (65 ft) wide, and was built on longitudinal grades ranging to 30% and cross slopes ranging to 20%.

The snow pad was built in November and December 1975 and pipeline construction, using the snow pad, was carried out in January through March 1976. The black spruce was cleared with a Hydro-Axe. Because snowfall was light during the early winter, the amount of natural snow available was not adequate to build the snow pad. No lakes were available in the area from which snow could be collected, although some snow was collected from portions of the nearby gravel pipeline construction. Therefore it was decided to manufacture snow at the Chatanika River over 30 miles to the south and haul it to the site.

The decision to manufacture snow at the river and haul it to the snow pad site involved a number of factors. Trucks carrying snow weighing less than 600 kg/m^3 (1,000 lb/yd^3) are underloaded and compaction at the site further reduces the effectiveness of the haul. On the other hand, snow can be manufactured at a water source with maximum efficiency without requirements for water haulage or storage. The snow can be hauled without special care but hauling water is difficult in severely cold weather. In addition, although Alyeska had the dump trucks to haul snow, they were not equipped to haul large quantities of water in insulated, and perhaps heated, tankers. Thus, Alyeska seems to have made a wise decision to manufacture snow at the Chatanika River, particularly since timeliness was probably more important than economy.

Snow was manufactured using a commercial snow maker and water pumped from the Chatanika River. A front-end loader stockpiled the newly made snow and loaded it into dump trucks for the trip to Globe Creek. The stockpiling, loading, and unloading of the snow helped to pack it and speed the age-hardening process.

A bulldozer was used at the site to spread each load of snow after it was dumped. The dump trucks were used to pack the snow and water tankers applied additional water. A motor grader was used to blade the snow and shape and smooth the snow pad. The pad was completed by mid-December, 1975.

Water was applied to the Globe Creek snow pad to increase its strength and density, but an ice cap was not formed. An ice surface on a slope such as that at Globe Creek may be of negative benefit because of traction problems.

Figure 1 gives an aerial view of the Globe Creek snow pad looking south. Figure 2 gives a view from the snow pad. Figures 3 and 4 show cores taken from the pad with a CRREL 3-in. ice-coring auger. Densities of these and other cores are shown in Table 2. It can be seen that the natural snow at the site was compacted from a natural in situ density of less than 0.20 g/cm^3 to values of 0.40 to 0.60 g/cm^3. The artificial snow, compacted when piled and loaded at the Chatanika River, further compacted at the snow pad and then watered, had densities ranging from 0.65 to over 0.85 g/cm^3. Snow becomes a porous ice somewhat above 0.60 g/cm^3, and solid ice has a density of 0.92 g/cm^3. Thus the Globe Creek snow pad was more like ice than snow.

Rammsonde tests were attempted but the material proved too hard and dense to penetrate with the standard Rammsonde, again testifying to its ice-like nature.

Figures 5-7 show some aspects of the trafficability of this snow pad. Figure 5 shows a pickup

Table 2. Density profiles of Globe Creek snow cores.

Note: Snow becomes ice-like at 0.65-0.70 g/cm³.

Location*	Type of snow	Height from ground surface (cm)	Density (g/cm³)	Location	Type of snow	Height from ground surface (cm)	Density (g/cm³)	Location	Type of snow	Height from ground surface (cm)	Density (g/cm³)
74 East	Natural	0-20	0.42	74 Center	Artificial	0-22	0.69	74 West	Natural	0-5	—
	Artificial	20-35	0.61		Artificial	22-37	0.725		Artificial	5-20	0.68
	Artificial	35-50	0.63		Artificial	37-58	0.72		Artificial	20-29	0.67
	Artificial	50-60	0.70		Artificial	58-72	0.75		Artificial	29-40	—
	Artificial	60-75	0.72								
	Artificial	75-90	0.73								
	Artificial	90-100	0.71								
	Artificial	100-120	0.72								
3420 East	Natural	0-10	0.53	3420 Center	Artificial	0-5	—	3420 West	Artificial	0-30	0.67
	Artificial	10-20	0.67		Artificial	5-18	0.71		Artificial	30-40	0.75
	Artificial	20-33	0.63		Artificial	18-33	0.80		Artificial	40-44	—
	Artificial	33-42	0.695		Artificial	33-42	0.75				
	Artificial	45-52	—		Artificial	42-45	—				
3820 East	Natural	0-5	—	3820 Center	Natural	0-10	0.585	3820 West	Artificial	0-12	0.83
	Natural	5-18	0.60		Artificial	10-20	0.725		Artificial	12-20	0.76
	Artificial	18-40	0.69		Artificial	20-30	0.85		Artificial	20-24	—
	Artificial	40-50	0.72								

*Locations indicated are at a pile bent (74) and two stations, 1834 + 20 and 1838 + 20. At each point, cores were taken from the east, center and west sides of the snow pad.

Figure 1. Aerial view of Globe Creek snow pad looking south. A = Buried pipeline. B = Built from snow pad. C = Globe Creek.

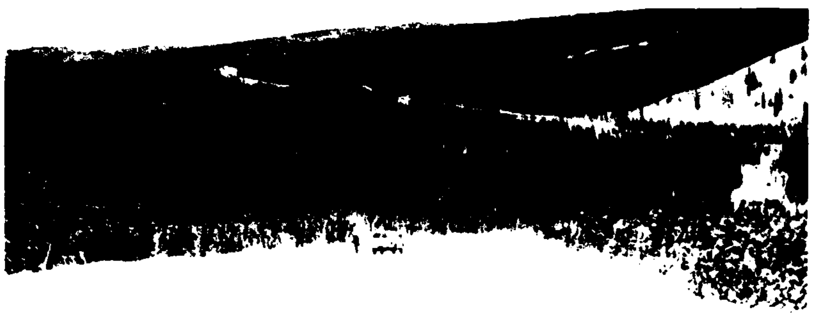

Figure 2. View of the Globe Creek snow pad looking downslope toward the north.

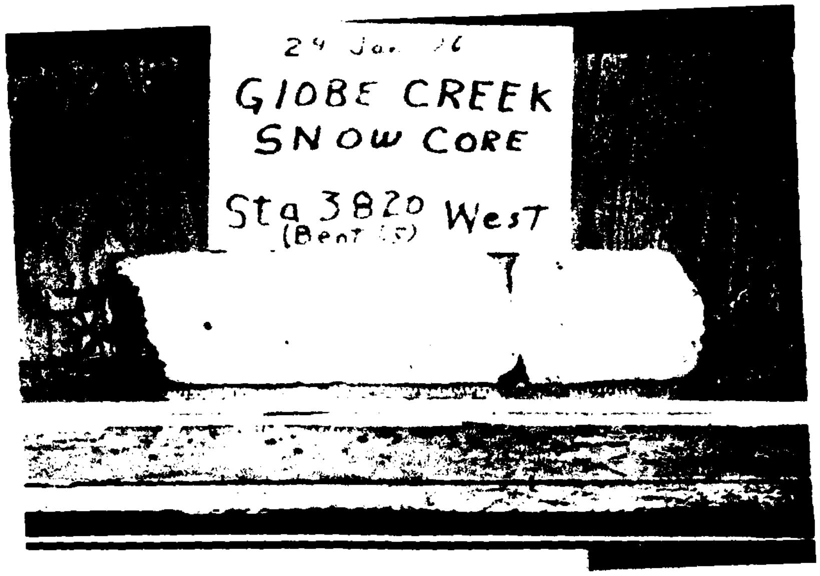

Figure 3. Globe Creek snow pad core.

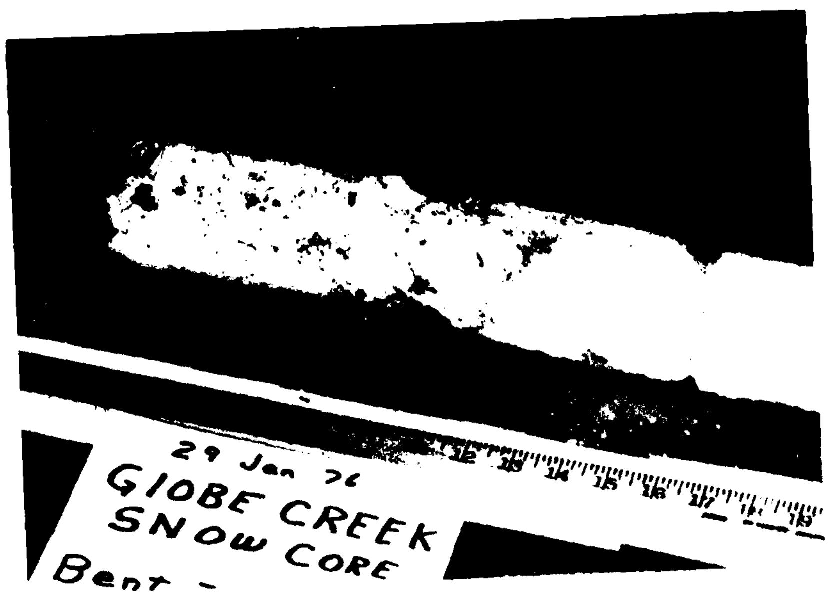

Figure 4. Another Globe Creek snow pad core. Packed snow can be seen next to the moss. Ice inclusions and packed and watered artificial snow can be seen to the right.

Figure 5. Pickup driving up 11% slope on the Globe Creek snow pad.

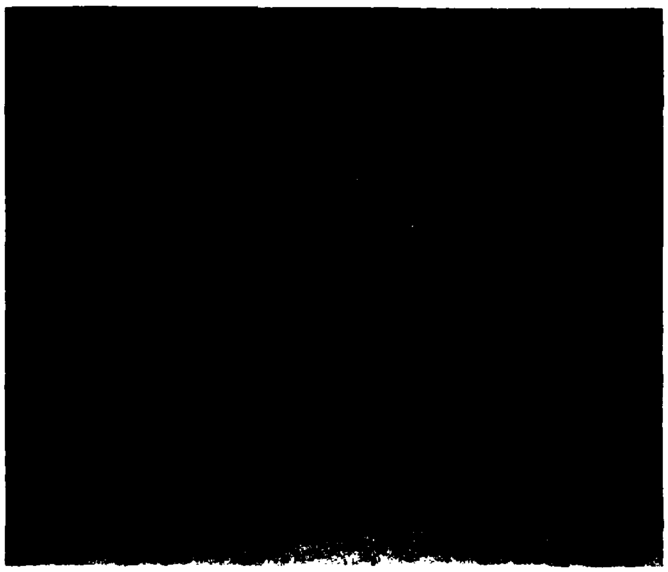

Figure 6. Caterpillar tractor cleats breaking up the upper surface of the Globe Creek snow pad.

Figure 7. Truck being towed up 17% grade on the Globe Creek snow pad.

driving up an 11% slope. The first few inches of the snow pad consist of loose granular material. Figure 6 illustrates the reason for the surface texture: cleated caterpillar tractors used on the snow pad broke up the surface. Figure 7 illustrates one reason for use of these tractors. A steeper slope at the beginning of the snow pad was 17% and, although light 4-wheel-drive trucks could climb this slope, conventional trucks such as dump trucks and busses experienced difficulty. In this situation, inexperienced drivers would spin their wheels, cutting more deeply into the snow pad. It was then necessary to pull the trucks up the slope as shown in Figure 7.

Alyeska guidance pointed out that adding sawdust or wood chips to the upper layers of a pad increases strength and improves traction on steep slopes. Whether using such additives and keeping tracked vehicles off the pad would have made it possible for dump trucks and busses to negotiate the slope shown in Figure 7 is not known.

Figure 8 shows the completed pipeline and the deteriorating pad on 20 April 1976. The snow pad begins in the valley in the foreground and proceeds part way up the distant hill. The vertical support members are each equipped with two thermal piles for ground-cooling purposes. The pipeline had been fully insulated and was complete. The initial steep slope out of Globe Creek can be seen in the curve of the pipeline. At the time the photo was taken, the spring thaw was well underway and wood and similar debris littered the surface, although the snow pad had not melted through in most places. One point where it had melted through can be seen in Figure 9, which shows the black spruce that had been processed with the Hydro Axe. Figure 10 shows the initial steep slope where the snow pad had melted at the top of the slope, while several feet of snow remained toward the bottom of the slope.

The Globe Creek snow pad provided an adequate surface for pipeline construction under difficult conditions. It apparently did not unduly compact the moss and destroy its insulation value, although further evaluation of the area is necessary. It demonstrated the utility of manufactured snow when natural snow is not available in adequate quantities. It also illustrated the problems of using snow pads on steep uphill slopes, particularly when cleated, tracked vehicles are allowed on the snow pads.

Figure 8. Completed Globe Creek pipeline and deteriorating snow pad, April 1976.

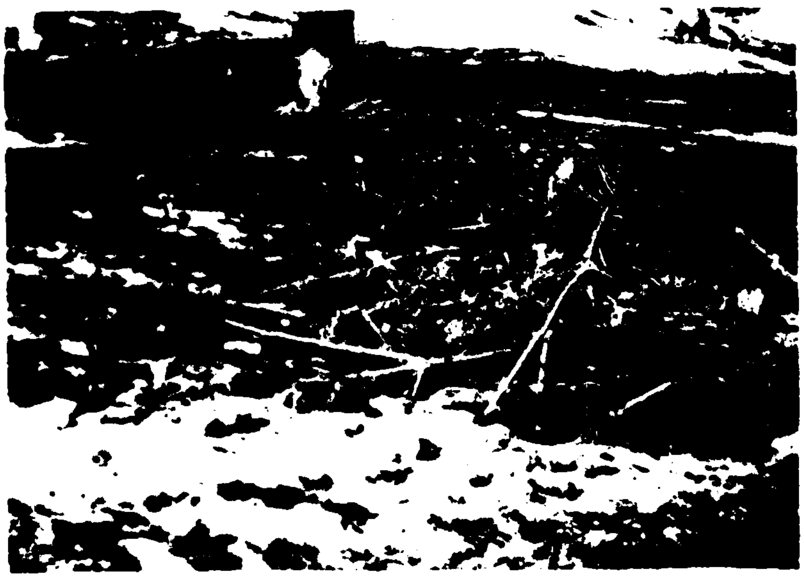

Figure 9. Globe Creek snow pad has melted through, showing scrub spruce processed by Hydro-Axe.

Figure 10. Initial steep (17%) slope at Globe Creek during breakup.

The Toolik snow pad

North of the Brooks Range most of the elevated oil pipeline was built on insulated gravel construction pads. In this case, extruded polystyrene insulation ("Board Stock") was laid on the tundra and then gravel was placed on the insulation. However, Alyeska was forced to build five miles of the 48-in.-diameter elevated pipeline between the Kuparuk and Sagavanirktok Rivers from a snow pad during the winter 1975-76. Snow for this pad was accumulated with a snow fence. Figure 11 shows a drilling rig on the snow pad; this photo was taken from the nearby Haul Road. Figure 12 shows the vertical support members of the pipeline in place, the snow fence, and another snow drift formed to the right of the snow fence. The cuttings from around the vertical support members were removed, and this snow pad was kept relatively free of dirt, oil and other materials that would absorb solar radiation and lead to early deterioration of the snow pad.

The Toolik snow pad varied from 30 to 60 cm (12 to 24 in.) in thickness but was generally nearly 45 cm (18 in. thick.). Irregularities of the underlying ground surface caused the irregularities in snow pad thickness. Ram hardness tests were attempted with a standard Rammsonde but the hardness of the pad exceeded the capability of the instrument. The density ranged from 0.50 to 0.60 g/cm^3. No water was added to the snow pad but a glazed surface developed from the wheeled traffic. Vehicles with cleated tracks traveled over the snow pad and tended to chip the surface but did not cause serious damage. The pad was graded as required to maintain a smooth, level surface. Grades were moderate, never exceeding a few percent. No failures in the pad were observed or mentioned by others before the breakup period. Traffic consisted of light and heavy drills, trucks, cranes, loaders, side boom tractors and other standard pipeline construction equipment.

In late April, the weather at Toolik warmed rapidly. Clear skies and more than 12 hours of sunshine accompanied the warm air temperatures; then the Toolik snow pad began to fail.

Temperatures during this period at Galbraith Airport are shown in Figure 13. Conditions at the Toolik snow pad were probably somewhat warmer since, by the end of April, temperatures were no longer freezing at night on this pad. The Toolik snow pad was closed on 2 May 1976; the temperature reached 9.5°C (49°F) on that date.

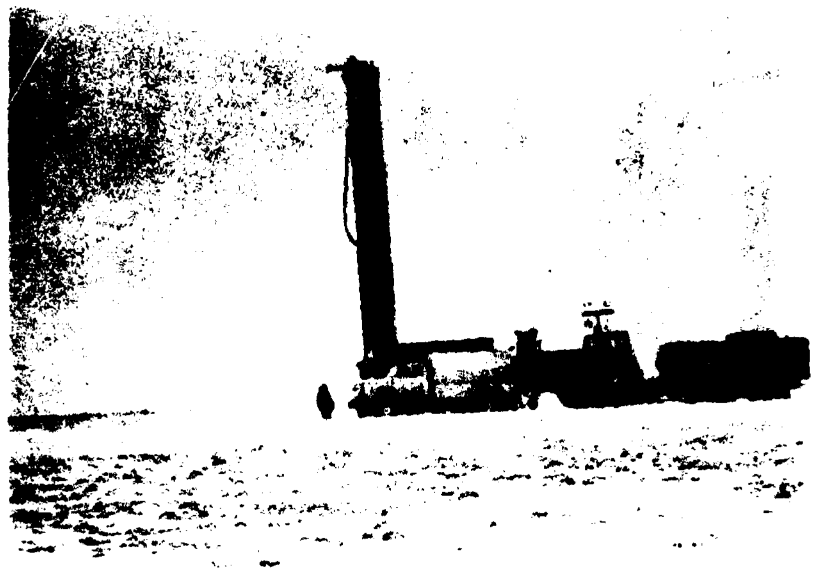

Figure 11. Heavy drill rig on the Toolik snow pad and the snowfence used to collect snow. Photo taken from the nearby state highway.

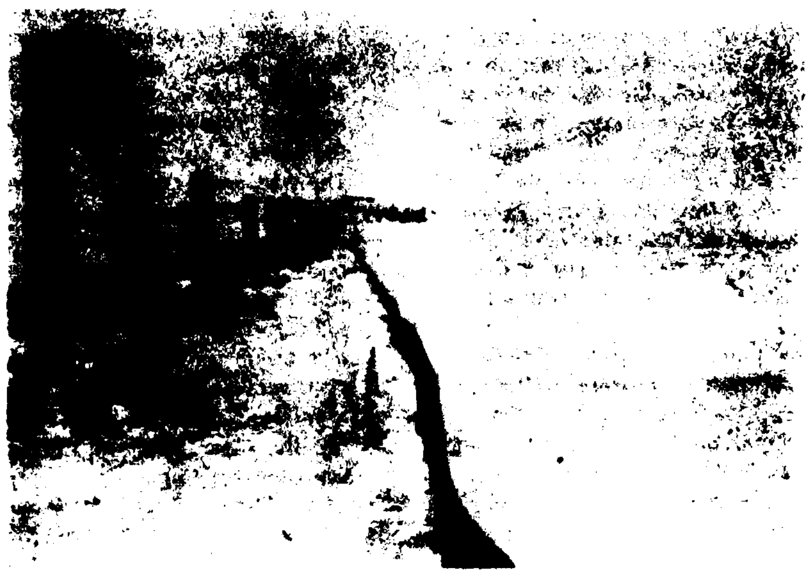

Figure 12. Pipeline vertical support members installed on the Toolik snow pad.

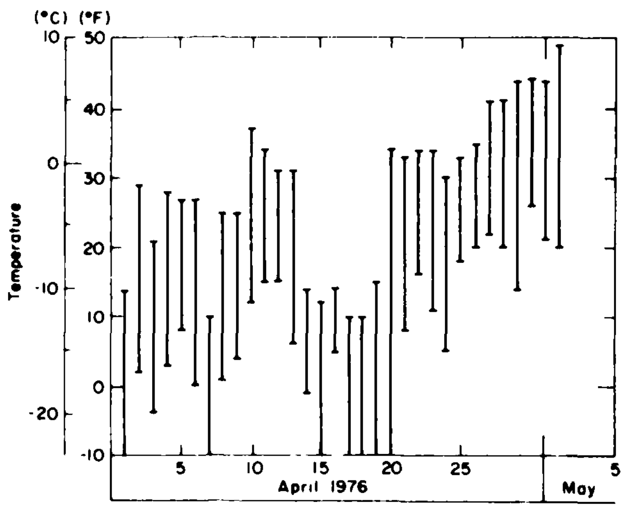

Figure 13. Galbraith Airport temperatures, April-May 1976.

The Toolik snow pad exhibited two types of failure during this period, as demonstrated in Figures 14-17. Figure 14 shows the south end of the snow pad beginning in the middle distance at the Kuparuk River. A closer view of this part of the snow pad, given in Figure 15, shows that the snow had turned to slugh. While a considerable thickness of snow still remained, it had no strength and wheeled vehicles sank deeply into it. At the north end of this pad, five miles to the north of the section shown in this photo, the failure was different and the snow pad turned to ice that melted away. Figure 16 shows the snow pad in this area as the ice was thinning. At one point, shown in Figure 17, the pad had thinned so that tractor grousers were contacting the tussock tops, this resulted in the closure of the snow pad. This appeared to be the total extent of the damage to the vegetation at the time the pad was closed.

Because of the early thaw, the pipeline was not completed in this section before the snow pad was closed. No other means of reaching the snow pad across the tundra was available, so further work was delayed until the following winter.

The gasline snow pad

Oil is pumped along the Trans-Alaska Pipeline by large gas turbines driving centrifugal pumps. The aircraft-type gas turbines can burn certain grades of oil or natural gas. Since, at the northern end of the pipeline, large quantities of natural gas are available, it was determined that natural gas would be supplied to Pump Stations 1-4, which lie north of Brooks Range. A small (8 to 10 in.) diameter fuel gas pipeline was designed to carry this gas. According to an agreement with the Alaska Department of Highways (ultimate owner of the Haul Road), in most areas, this 237-km (147-mile) pipeline was installed on the downhill side of the Haul Road, 4.6 m (15 ft) from the toe of the grade except at cross-drainage locations where the pipeline would be placed further from the road.

The gas pipeline design called for installation of the line from a snow pad. Snow was in limited supply at the south end of the line, but easterly storms had deposited some drifting snow along the west shoulder of the Haul Road. Part of this snow was pushed further from the road, leaving a snow trap. This system is shown in Figure 18. The snow pad was built by spreading and packing the snow (Fig. 19), dragging it with various types of drags (Fig. 20 and 21), and leveling and further smoothing it with tractors and motor graders (Fig. 22).

The thickness of the snow pad varied from 10 to 36 in. and was controlled, in large part, by the cross slope. An effort was made to measure the hardness of the completed snow pad but, where the pad had age-hardened, it proved impossible

Figure 14. Looking north to the Toolik snow pad during spring breakup. The snow pad begins in the valley in the middle distance.

Figure 15. Closeup of the south end of the Toolik snow pad as the packed snow turned to slush, 1 May 1976.

Figure 16. View of the north end of the Toolik snow pad, 1 May 1976. The snow had turned to ice and was thinning as it melted.

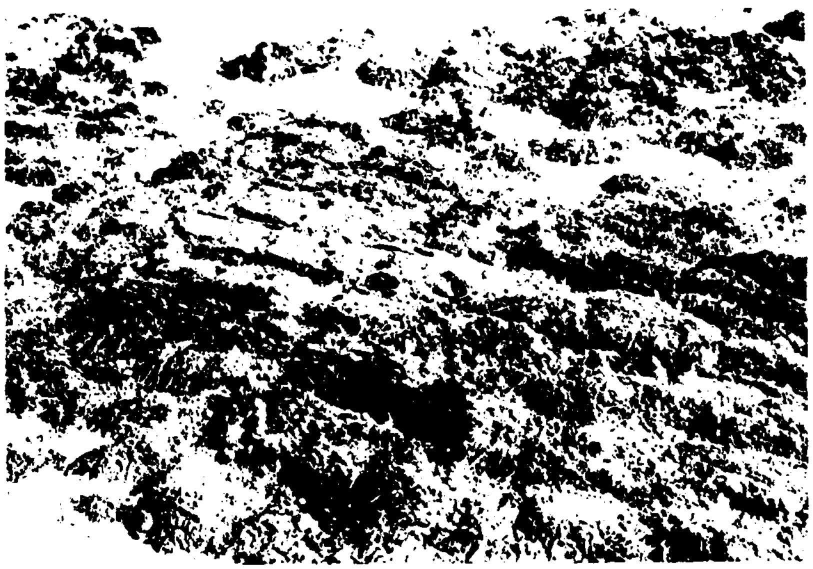

Figure 17. Final stages of the disappearance of the north end of the Toolik snow pad showing where tractor grousers contacted tussock tops.

Figure 18. Snow trap formed in a roadside drift near Galbraith Lake.

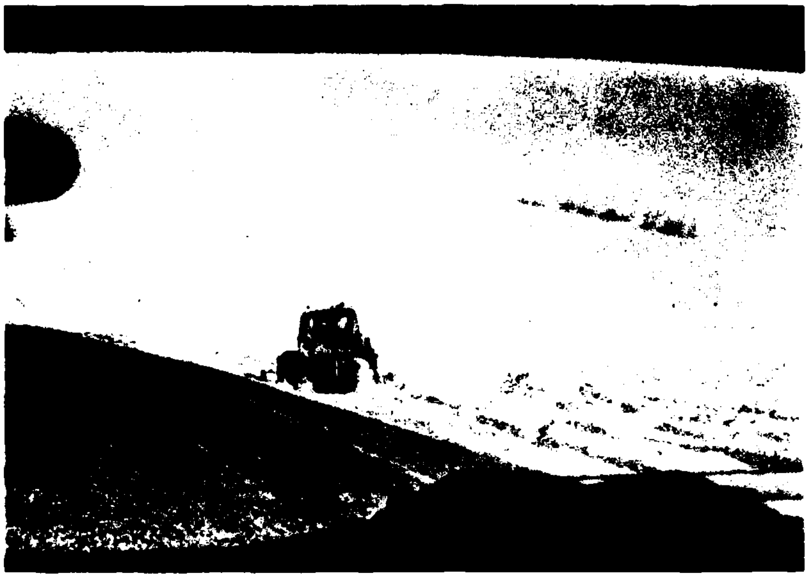

Figure 19. Spreading the collected snow to form the fuel gasline snow pad.

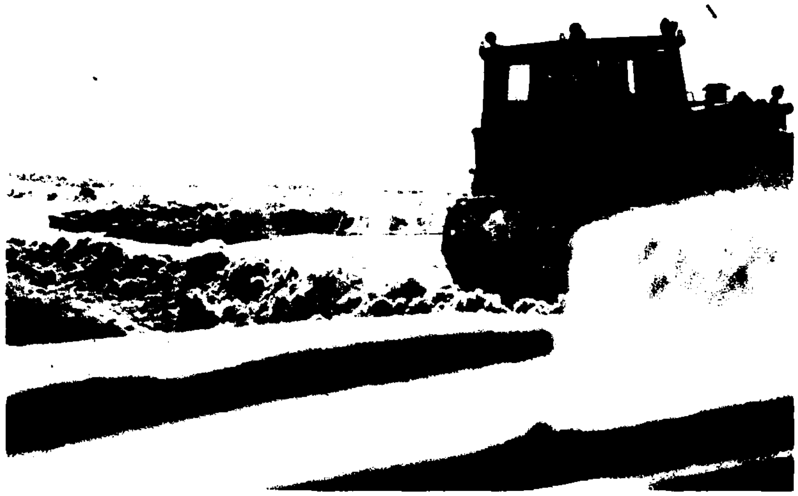

Figure 20. Dragging the gasline snow pad with a timber drag.

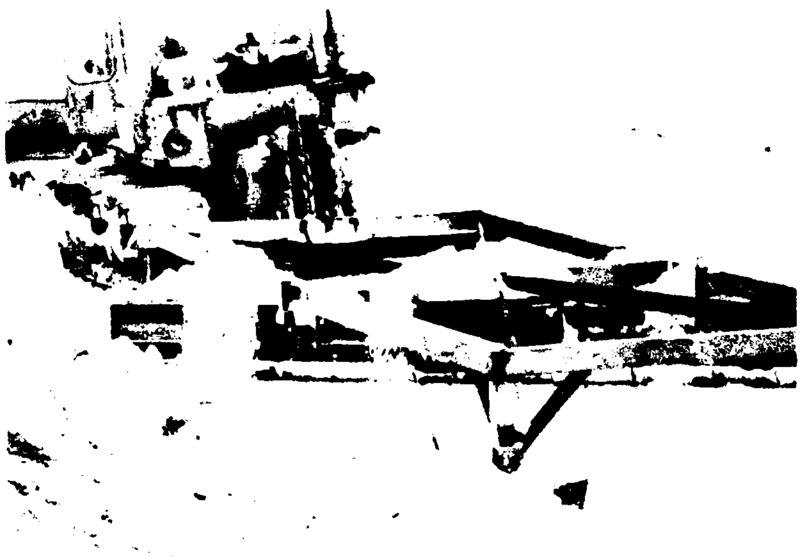

Figure 21. Dragging the gasline snow pad with a blade on a ski-mounted frame.

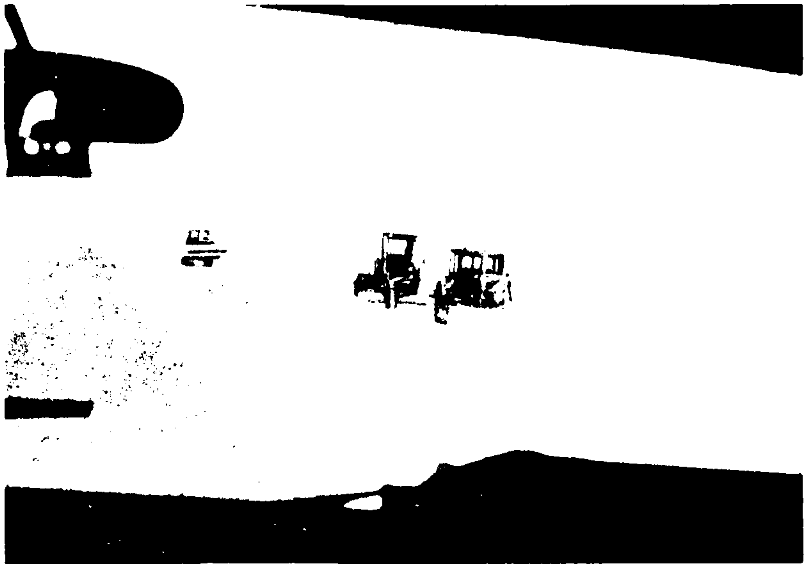

Figure 22. Smoothing, packing, and leveling the gasline pad.

to measure the snow properties with the Rammsonde and standard snow density equipment. Consequently, it was decided to test a section that had not yet fully age-hardened.

The snow pad 200 ft north of the Galbraith Camp entrance was selected for testing. The snow in this section had been spread with a bulldozer on the evening of 26 February 1976, and the snow pad was further shaped and graded on the morning of 27 February. The geometry and ram hardnesses were obtained on the morning of 28 February 1976, one day after the pad was finished.

The ram hardness values obtained on the snow pad 200 ft north of the Galbraith Camp entrance on 28 February 1978 are shown in Table 3. Several points are apparent. First, ram hardness values near the top of the snow pad were relatively high and some additional time would provide a snow pad that would handle the expected traffic. Second, the underlying snow near the toe of the roadway was relatively soft. This could be expected as this was the original snow accumulation area. Snow was removed from this area and the surface snow was worked and packed; however, the packing did not penetrate enough to seriously disturb the snow at the toe of the slope. Third, hard snow was found near the outer edge of the snow pad. The reason for this was that this snow was from the upper part of the snow drift and such snow tends to be harder than that below. Much of this snow had been processed previously, as shown in Figure 18. The snow in the outer portion of the pad consisted, in large part, of hard snow "boulders" that had been pushed and rolled to the outer side of the snow pad. Voids between these snow "boulders" were partially filled with loose snow that had also been pushed outward into this area.

Table 3. Ram hardness of gasline snow pad near the Galbraith Camp entrance.

Depth from pad surface		Distance from east edge of snow pad				
(in.)	(cm)	45 ft	35 ft	25 ft	15 ft	5 ft
2	5	462	282	462	600	860
6	15	619	349	274	214	274
10	25	484	49	239	154	214
14	36	379	94	154	139	
18	46	334	131	154	124	
22	56	259	42	169	108	
26	66	199	214			
30	76	184	79			
34	86	124				

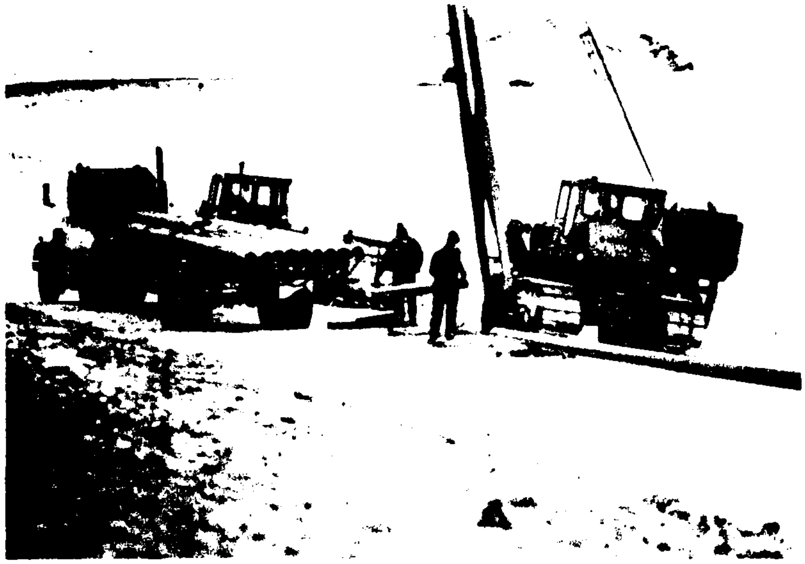

Figure 23. Stringing the pipe on the gasline snow pad.

Generally the snow pad in the southern area, where construction began, was formed shortly before it was used for trenching, stringing pipe and other early construction activities. Despite the lack of adequate time to harden and the fact that no water was applied, it generally performed well. Two cases where problems were encountered are described below.

Pipe stringing and welding preceded trenching in some sections. The pipe was strung on the snow pad using conventional truck-trailer rigs and side boom crawler-tractors to handle the pipe (Fig. 23).

Figure 24 shows the gasline snow pad crossing a drainage area with a fairly long and moderately steep grade. In this area loaded conventional trucks were pulled uphill by crawler tractors. Figure 25 shows a truck loaded with pipe cutting into the snow pad on a moderate upgrade in another area. Figure 26 shows this area after additional traffic. Most vehicles were able to drive through; these photos, however, do indicate that special care and perhaps special treatment are required on upgrades.

Trenching was carried out from the snow pad either by cutting with a Roc Saw (Fig. 27) or by drilling and blasting (Fig. 28). The blasted area was then trenched with a backhoe (Fig. 29).

Part of the backfilling was carried out from the snow pad. Figure 30 shows a conventional large trailer dump truck bringing backfill material to the site. The contractor chose to spread this material as a gravel pad on the snow pad and then blade it into the trench. Figure 31 shows the partially backfilled trench; Figure 32 shows the final backfilling after insulation had been placed in the trench.

As the season progressed and the snow pad began to soften, other methods of backfilling were employed from the road rather than from the snow pad. Figure 33 shows a clam shell equipped crane being used from the Haul Road and Figure 34 shows a conveyor system picking gravel from the road and dropping it into the trench.

Difficulties were encountered in cleaning the dirt and gravel from the snow pad after construction was completed. Figure 35 shows a point where the head of a culvert was dug out; the covering of dirt and gravel was several inches thick. Figure 36 shows a Gradall being used to clean the pad at another site.

The environmental impact of the snow pad is not yet completely assessed (Johnson 1980). Figures 37 and 38 show a section of the pipeline that had been installed in a trench cut by a Roc Saw. The location of the snow pad is clearly evident in Figure 37 but Figure 38 indicates that much of the visual alteration is due to small quantities of dirt and gravel on the tundra.

Figure 24. Gasline pad crossing a drainage area. The near grade was long and moderately steep and trucks were pulled up.

Figure 25. Truck loaded with pipe cutting into the snow pad on a moderate upgrade.

Figure 26. Disaggregated snow pad surface where loaded conventional trucks encountered a moderate upgrade. (Same area as in Fig. 25).

Figure 27. Trenching from the snow pad using a Roc Saw.

Figure 28. Drilling and blasting for the gasline trench from the snow pad. Photo taken from the adjacent state highway.

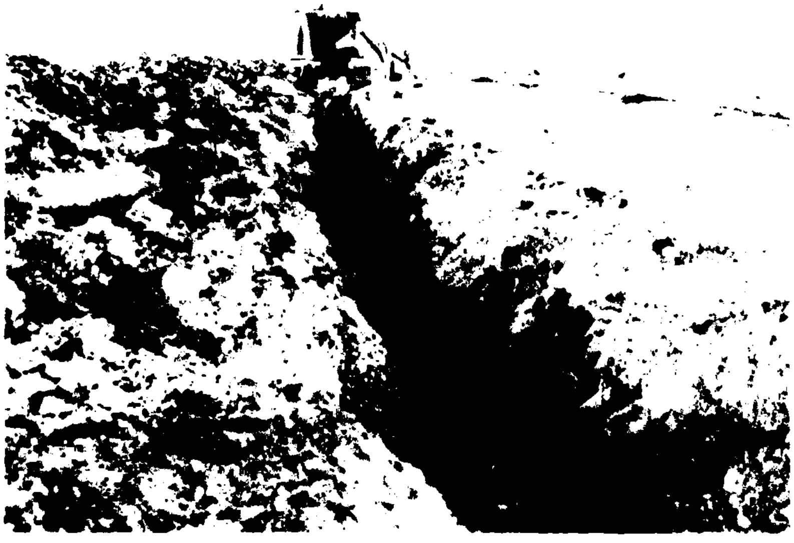

Figure 29. Trenching with a backhoe after drilling and blasting. See Figure 28.

Figure 30. Dumping backfill material for the gasline trench on the snow pad. The trench is at the near edge of the gravel.

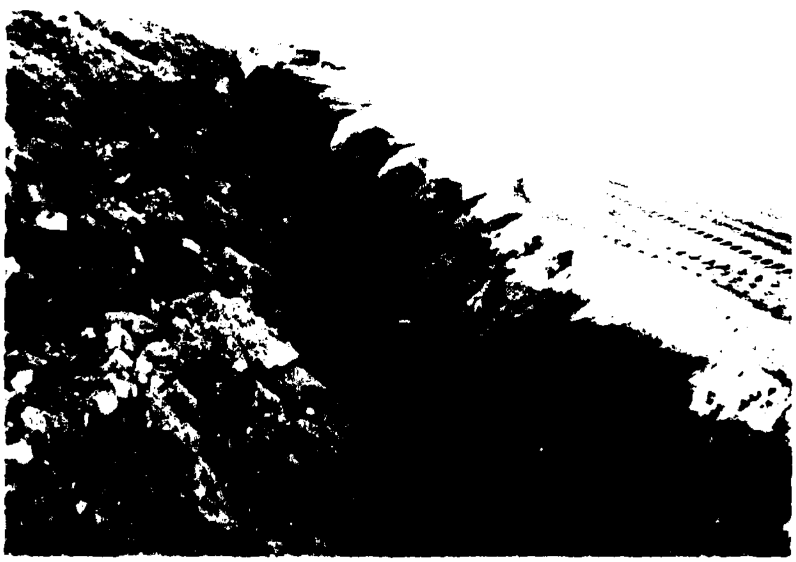

Figure 31. Gasline trench partially backfilled by blading in the gravel.

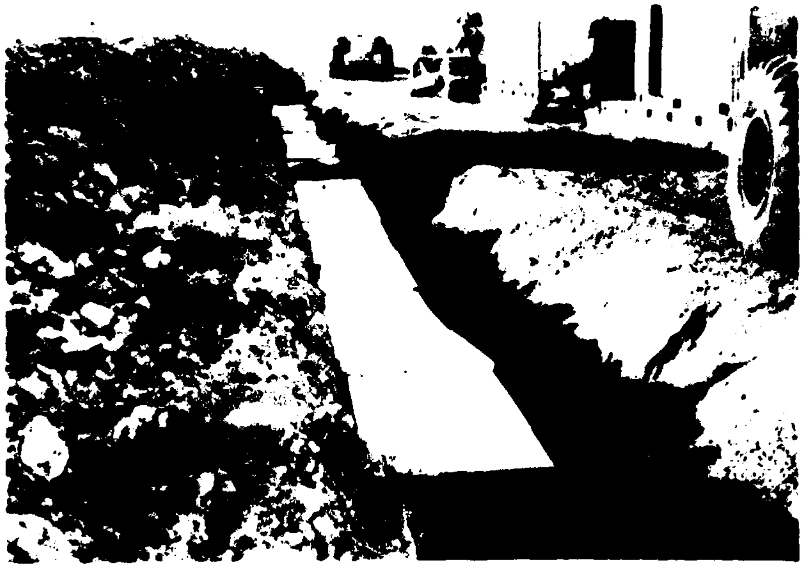

Figure 32. Final backfilling of the gasline trench after placement of the insulation.

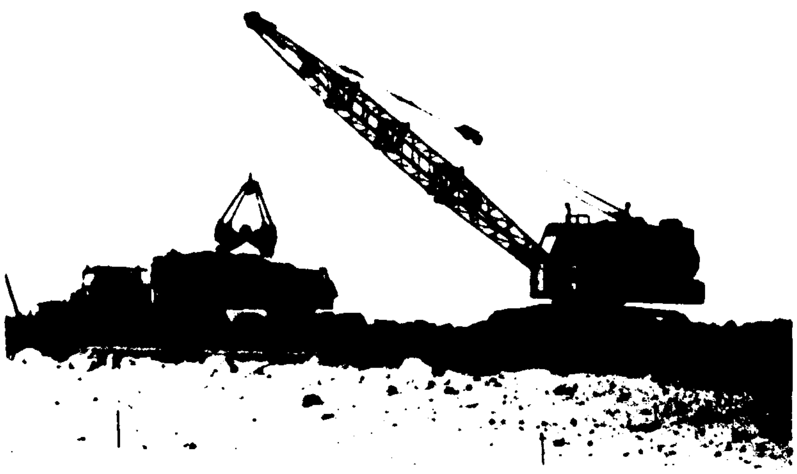

Figure 33. Backfilling the gasline trench from the road with a clam shell.

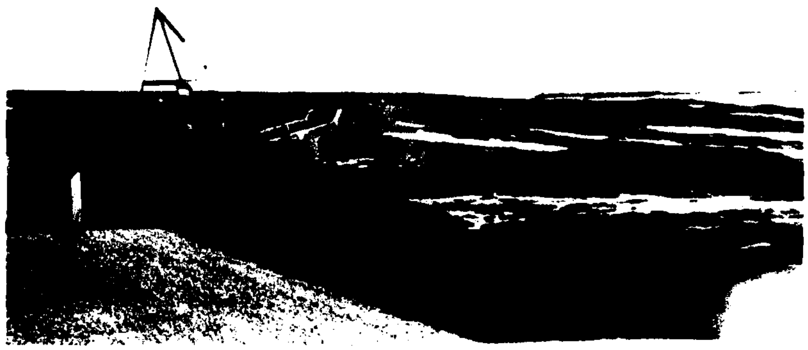

Figure 34. Backfilling the gasline trench from the road with a conveyor.

Figure 35. Debris on the gasline snow pad.

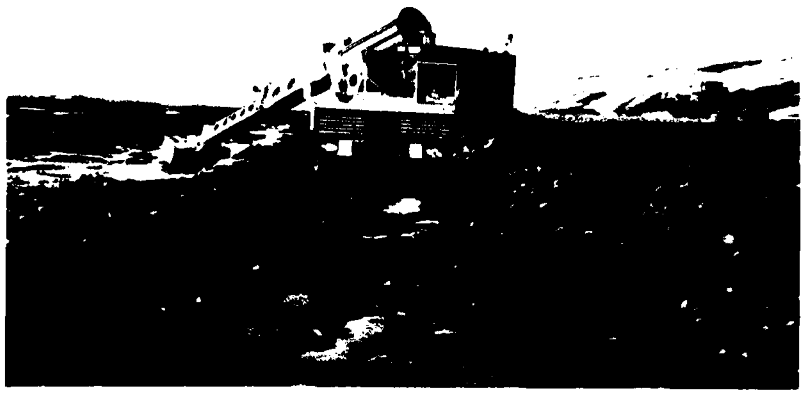

Figure 36. Cleaning the gasline snow pad with a Gradall.

Figure 37. Completed gasline. The only indication of the snow pad is the slight discoloration of the tundra. The gasline is near the road.

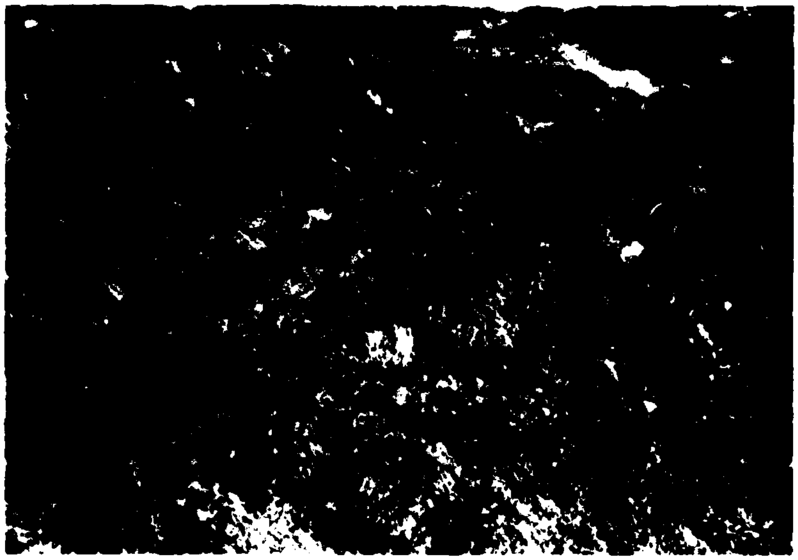

Figure 38. Closeup of completed gasline.

Figure 39. Another view of the completed gasline. In this location the gravel backfill extends slightly above the surrounding tundra.

Figure 39, a photo taken nearby, shows the pipeline backfill somewhat elevated above the tundra surface and limited quantities of dirt and gravel on the tundra. None of these pictures shows any sign of wheel or tractor tracks on the tundra and very little compression of the vegetation.

The snow pad used to build the gasline, like the nearby Toolik snow pad, failed earlier than expected due to the warm, clear weather in late April and early May. The contractor was not able to complete the gasline during the winter construction season of 1975-76; therefore, the balance of the line was scheduled for construction, also from a snow pad, during the winter of 1976-77.

SUMMARY AND CONCLUSIONS

The three snow pads used by Alyeska Pipeline Service Company during the winter 1975-76 were generally successful in providing a surface for construction while protecting the underlying vegetation and permafrost.

Snow shortages were encountered at all three locations of the snow pads. At the Globe Creek site, Alyeska manufactured snow at a water source and hauled the snow to the pad. The cost of manufacturing the snow was probably moderate, but the cost of hauling was undoubtedly substantial. However, it appears that this system was the best of the several alternatives at that time and place. At the Toolik snow pad, Alyeska captured adequate snow with a simple snow fence and thus obtained the material on site for a very moderate cost. The gasline snow pad used an existing snow trap, the Haul Road itself, to obtain part of the required snow. Part of this drift was then pushed out to improve the effectiveness of the snow trap and an adequate supply of snow was captured at moderate cost. It seems probable that lack of snow will be a problem in the Subarctic and Arctic wherever snow roads or pads are planned.

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